

# **AUBE '01**

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## **PROCEEDINGS**

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## **Fire Protection Systems for Traffic Tunnels Under Test**

### **1. Introduction**

Underground transport facilities are sensitive links in the economic chain that carry thousands of people and tons of goods every day and they are growing in importance. Therefore a breakdown in operations can have catastrophic consequences. That is why safety precautions are vitally important and the work involved is commensurate with the high potential risk. By far the greatest risk is a fire out of control. There is great danger to life from toxic combustion gases, exceedingly high temperatures, total loss of visibility, limited means of escape and the panic reactions of drivers and passengers. The emergency services are usually hindered by vehicles and by the smoke and gas generated by the fire which at the same time causes serious damage to the infrastructure of the transport facility.

The dramatic events in the Mont Blanc and Tauern tunnels triggered a wide public debate on the safety of road and rail tunnels leading to demands for comprehensive safety precautions to safeguard the survival of travellers, to keep damage to the facility to a minimum and to maintain its availability.

Structural and organizational measures such as refuges, escape tunnels, effective smoke-venting and rescue concepts are an important first step. Equally important for the prevention of a catastrophe are

- fire detection which is fast, reliable and indicates the precise fire location without being influenced by high-speed air currents

- automatic activation of traffic control systems, the alerting of the emergency services, a fire spread assessment at the scene of the accident, the activation of ventilation systems etc.
- the activation of extinguishing systems to keep the fire in check until the fire department arrives at the scene of the accident.

As with all high-risk installations, those underground call for systems offering the highest reliability. Furthermore, early and certain detection and immunity to false alarms is of the greatest importance. What previously was a very basic form of fire detection for tunnels has, in recent years, developed into a special discipline which has had a powerful influence on the entire security concept for underground transport facilities.

## **2. Aim and purpose**

Concepts for electronic security systems have existed for years and have been consistently upgraded. However, the question is, how the effectiveness, the reliability and immunity to interference of the systems proposed can be practically tested using the previously made physical calculations. Similarly, the test environment, i.e. the location or the premises as well as the technical installations play a decisive role in such tests. The following description deals with these tests with emphasis on fire detection and extinguishing.

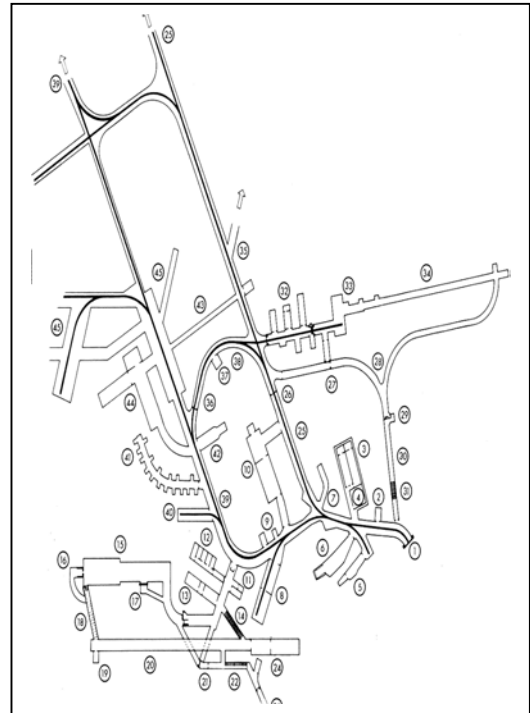
## **3. Test Infrastructure**

The Hagerbach tunnels near Sargans in Switzerland offer almost ideal conditions for the tests. Hagerbach comprises approx. 4500 m of underground tunnels of various lengths equipped in different ways. It is mainly used for research into new methods of tunnel construction as well as demonstrations (see “The Siemens Magazine – New World No. 3“, August 1999).



Entrance to the Hagerbach (Switzerland)

test tunnel



The plan of the test tunnels. The tunnel

complex consists of approx. 4500 m tunnel sections of varying lengths and equipped in different ways

The extract air tunnels with wind speeds of up to 5 m/s, are particularly good for genuine fire and extinguishing tests. For this purpose the floor of the used air tunnel was concreted and fitted with a sump to collect the waste water resulting from extinguishing tests. Various temperature sensors, which can be located wherever required, measure convection and radiant heat. The air speed is also measured. The early warning flame detectors signal the first open fire in a series of tests. The entire test area for fire and extinguishing tests is monitored by video cameras. The control centre was set up some distance away and monitors the test equipment and measuring devices and records all test, measuring and graphics data.

In addition to pool fires for the simulation of rail and road vehicle accidents, a specially-designed dummy vehicle is used to re-create various fire sequences as well as the assessment of the effect of extinguishing in different extinguishing configurations.



Test set-up in tunnel with dummy vehicle.



The control center with its monitors.

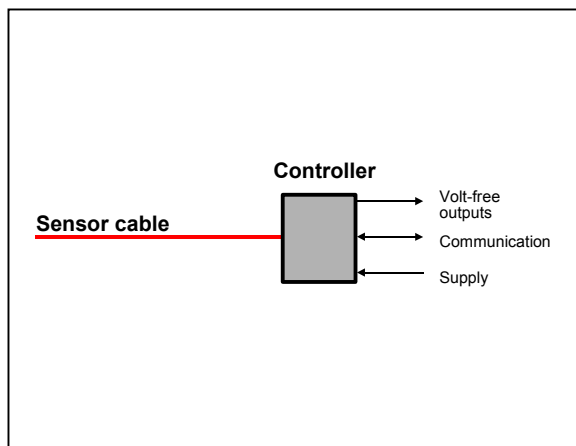
As the test tunnel with a height of 3m and a width of 3m is smaller than a standard tunnel, the measurements were scaled down to provide a mathematically correct basis for proper tests. Thus the procedure could be used for the application of test results for tunnels with different dimensions, lane directions and ventilation conditions. The “Scaling Up / Down“ calculation is part of the VdS test for the FibroLaser II calculation program (see also section 4.2).

## 4. Testing systems

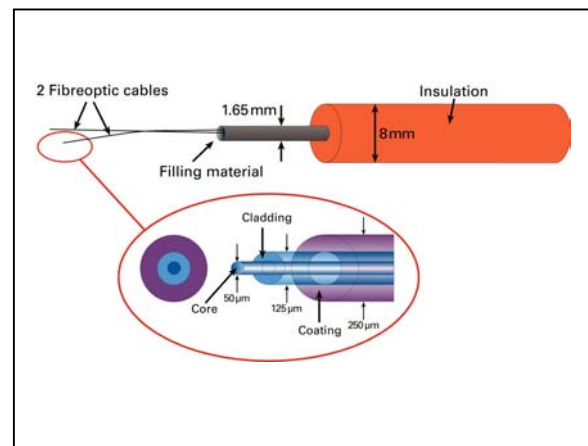
### 4.1 Fire detection with FibroLaser II

The FibroLaser II fire detection system is used for fire detection in tunnels. The system is an intelligent heat detector connected to a fire detection control unit and as required can provide detailed alarm information for further processing. FibroLaser II has a simple system architecture:

- Fibreoptic sensor cable up to 4 kilometers long
- Controller with laser light generation and software-supported evaluation
  - Volt-free outputs for alarm and fault messages
  - Communication interface for the setting of the optimized operating parameters for the tunnel concerned during commissioning and for a link to the control and visualization units with no retroactive effect
  - Power supply 24V DC or 220V AC (100W)



System architecture FibroLaser II



Design of FibroLaser II sensor

cable

The sensor cable consists of a steel capillary tube with an outer diameter of 1.65 mm. The capillary tube contains 2 separate quartz fibers each with an outer diameter of 0,25

mm. The remaining space in the capillary tube is filled with an anhydrous, heat-conductive material.

The steel capillary tube is encased in a plastic coating with a diameter of up to 8 mm. This plastic coating makes handling easier during installation and provides mechanical stability as well as sensitivity to strictly radiated heat.

The FibroLaser II fire detection system is VdS listed. FM and UL listings are pending.

The FibroLaser II sensor cable was installed at different locations along the roof and walls of the tunnel in the test set-up in order to be able to record all reactions to convection and radiant heat. In addition, by placing the sensor cable of FibroLaser II in cable raceways in the vicinity of the tunnel test section, it is possible to determine heat detection capability in bunches of cables, cable ducts etc.

#### 4.2 Calculation program for FibroLaser II

The planning of tunnel fire detection systems is very demanding as wind speeds have to be taken into account in addition to traffic conditions and geometric dimensions.

A calculation program (patent applied for) has been developed to check the effectiveness of the fire detection system as planned and works out the response time of the FibroLaser II on the basis of the tunnel dimensions, the fire load and wind speeds etc. Known or assumed parameters are entered in the input template of the calculation program. The result is presented in table form or as graphics.

The series of fire tests in the Hagerbach tunnels has provided valuable basic data which, supplemented with results from fire tests in real tunnels has yielded the basis for the mathematical model of the calculation program.

The calculation program is VdS listed. As already mentioned, this review includes the “Scaling Up / Down” process.

### 4.3 Fire detection with video

Fire detection with video or so-called “cold fire detection” is frequently mentioned in publications at the moment. However, so far no video system has been produced for application in tunnels which can independently guarantee reliable and false alarm free fire detection and which has international approval. Nevertheless, video technology is making great strides.

For this reason provision has been made in the Hagerbach installation to enable new developments in video technology to be tested.

### 4.4 Extinguishing

Extinguishing systems for tunnels are specially designed water spray systems with nozzles modified to the type of tunnel in order to guarantee the best extinguishing effect. The extinguishing system is automatically actuated at the fire location by the FibroLaser II system. This means that extinguishing is only triggered at the fire location and that no other vehicles in the tunnel are involved. This procedure also allows us to keep extinguishing water supplies and the amount of waste water to a minimum.

Extinguishing systems in tunnels must be able to withstand the special ambient conditions such as below-zero temperatures or corrosive exhaust gases. Furthermore, the extinguishing system must be able to bring the fire under control in spite of powerful air currents.

Water pipes for servo-mechanical nozzles are mounted along the roof and walls of the tunnel section of the test installation. This simplifies the evaluation of the various extin-



guishing configurations. The pressurized water is supplied via an arrangement of pumps which enables not only the water pressure to be varied, but also different rates of flow. It is also possible to introduce additives into the extinguishing water. The waste water from the extinguishing system is collected in sumps and correctly disposed of. Gas detection



The extinguishing water pump station

perm



Tanks for the disposal of waste water

VdS approval of the extinguishing system described is pending.

#### 4.5 Systems engineering

In the field of systems engineering emphasis is on practical tests for operating sequences.

System specialists work out the interfaces, interactions, data communication and control system technology in accordance with customers' specifications.

### **5. First findings from the test series**

The series of tests at the Hagerbach test tunnels have the following objectives:

- Validation of the calculation program for the optimum application of FibroLaser II
- Examination of the “Scaling Up / Down“ method, which enables configuration of the detection system irrespective of the size of the tunnel
- Optimization of tunnel extinguishing in the form of a water spray deluge system with minimum water consumption

When validating the calculation program, (PC software) particular attention is paid to examining the following thermodynamic phenomena:

- Combustion behavior according to the type of combustible and the fire surface
- The influence of the wind on the rate of combustion and on the mixing of combustion gases
- The radiated power of the fire on the FibroLaser sensor cable

- The convection heat exchange with the FibroLaser sensor cable

Previous tests have shown that the tunnel wind, especially that from the emergency ventilation, which in the event of a fire is switched on to disperse the smoke, has a decisive influence on the course of the fire and detection. Furthermore, it has been proved that the linear detection of the radiated heat of a fire is the only relevant alarm criterion at higher wind speeds. As the radiated heat is not influenced by the tunnel wind, the fire location can also be precisely determined.

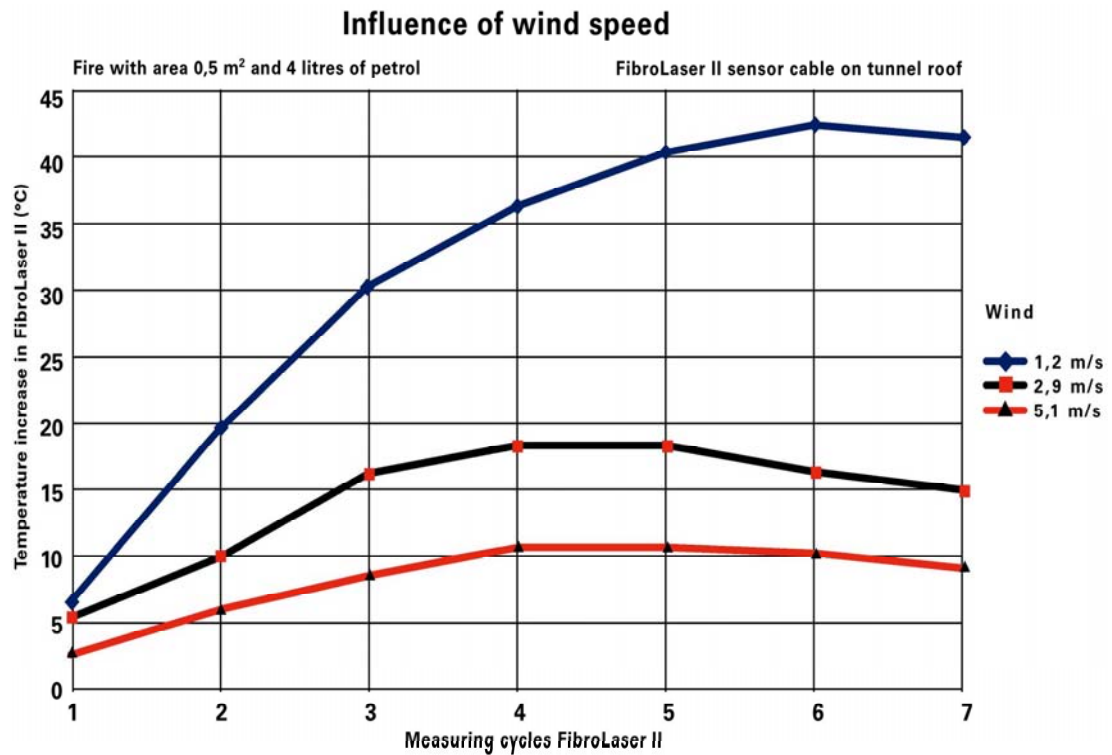


Diagram of fire test results

The diagram above shows the results of fire tests in the Hagerbach test tunnels with a petrol fire (4 liters) covering 0,5m<sup>2</sup> and various wind speeds. This size of fire is equivalent to that involving one car.

The diagram clearly shows the influence of wind on detection and the combustion time. In this particular case only the field of radiation is detected. The combustion gas temperatures beneath the roof of the tunnel lie below the measured values in the FibroLaser sensor cable.



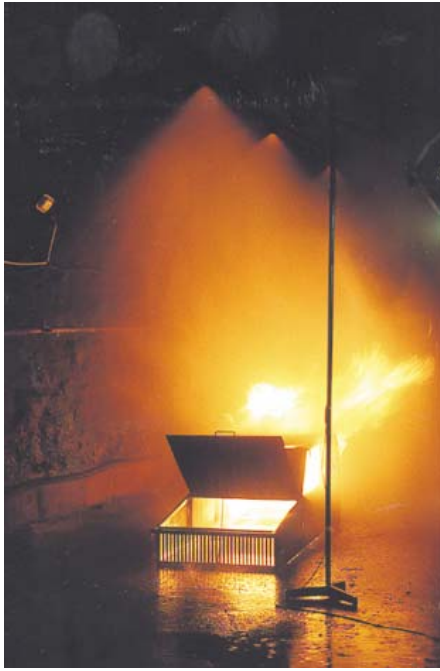
The test with dummy vehicle without tunnel wind at fire source



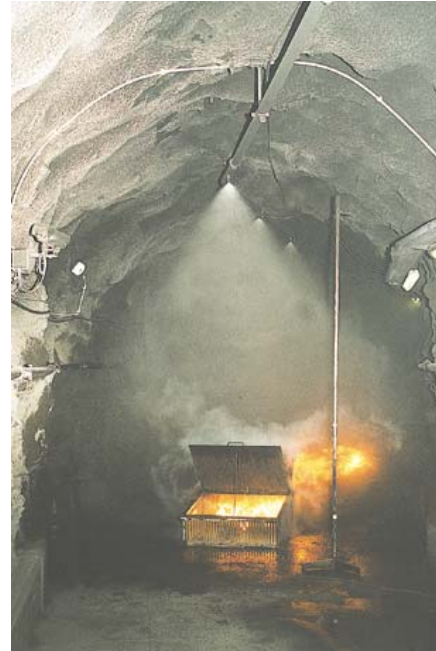
The test with dummy vehicle and a tunnel wind of  $\sim 5\text{m/s}$  at fire source

An important aspect for the interpretation of the Hagerbach tests is the “Scaling Up / Down“ procedure. Tests in small or large tunnels must be comparable and it must be possible for the calculation program to process them irrespective of tunnel geometry. Experience shows that empirical values are the decisive parameters for the conversion of the specific radiation volume and the specific calorific output of a fire.

Tunnel fire extinguishing is based on an optimized water spray deluge system with a nozzle concept that achieves its protection aim with minimum water consumption. Fire tests with a dummy vehicle and realistic combustibles (plastics, petrol, rubber etc.) show that the protection aim must be to bring the fire under control in the vehicle where it originated and to prevent fire spreading to the surrounding area. It has proved to be essential to extend the coverage area of flooding to zones of approx. 30m, whereby basically the extinguishing system in the zones adjacent to the zone in which extinguishing has been actuated should also be actuated. With FibroLaser II it is possible to locate the fire to within about 3-4m and to register the spread of hot gases.



Extinguishing test with fire in the dummy vehicle and a tunnel wind of  $\sim 3$  m/s at fire source



Extinguishing test with fire in the dummy vehicle and a tunnel wind of  $\sim 5$  m/s at fire source

## 6. International activities in tunnel protection

Following the tragic accidents in spring 1999, groups of experts were formed in a number of countries to check existing tunnels and to work out plans for the realization of comprehensive concepts for tunnel safety. It is hoped that some of these projects will be financially supported by national authorities. The scope of these concepts stretches from structural measures such as escape tunnels, the design of ventilation systems, electronic security systems and extinguishing systems, to training centres for the emergency services.

Within the framework of such schemes Siemens Building Technologies Ltd., Cerberus Division can make a solid contribution towards the protection of tunnels.

The author of this paper, Rudolf Maegerle, is Head of Application Support at Siemens Building Technologies Ltd., Cerberus Division and is also responsible for the development and application of new products.